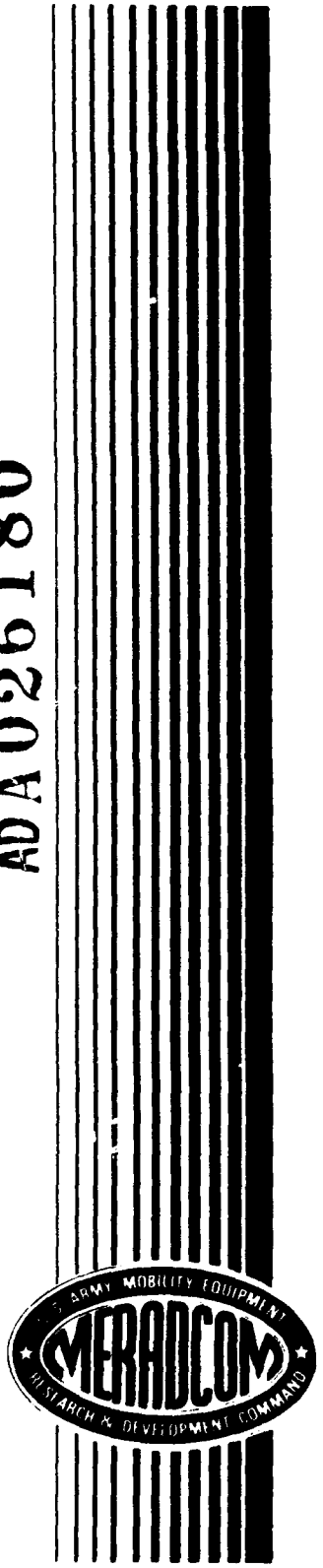

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Report 2164

SILICONE BRAKE FLUIDS: TWO-YEAR FIELD TEST

January 1976

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U.S. ARMY MOBILITY EQUIPMENT
RESEARCH AND DEVELOPMENT COMMAND
FORT BELVOIR, VIRGINIA

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A study was conducted to evaluate the performance of silicone brake fluids in military vehicles operating under various climatic conditions. These fluids were field tested for two years in vehicles operating at the Tropic Test Center (TTC), Panama Canal Zone and the Yuma Proving Ground (YPG), Arizona and for one year at the Arctic Test Center (ATC), Fort Greeley, Alaska. After two years service at the TTC and YPG, the water intolerant silicone fluids were significantly better than the water tolerant silicone and the conventional brake

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fluid with respect to metal corrosion. At ATC, tests on the two water intolerant silicone fluids were discontinued because of possible crystallization at low temperatures and were replaced midway through the first year with fluids having improved low-temperature properties. These fluids were superior to the MIL-H013910 arctic brake fluid after one year's service.

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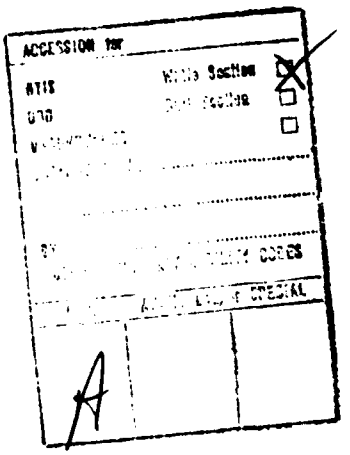

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SILICONE BRAKE FLUIDS: TWO-YEAR FIELD TEST

I. INTRODUCTION

The Army uses three types of automotive hydraulic fluids. These are covered by Specifications VV-B-680, "Brake Fluid, Automotive," for operations ranging from plus 55°C to minus 30°C; MIL-H-13910, "Hydraulic Fluid, Polar Type, Automotive, All Weather," for operation to minus 55°C; and MIL-P-46046, "Preservative Fluid, Automotive Brake System and Components," for brake systems of vehicles in storage and as a packaging fluid for wheel and master cylinders.

In 1967, because of the success of silicone fluids in hydraulic applications, makers of these fluids became interested in developing a single all-purpose fluid to overcome the water sensitivity of current fluids as well as to provide all-weather and preservative properties. The producers were encouraged to develop such a fluid since it would reduce maintenance and logistics costs substantially by providing increased brake system reliability; eliminating the need to change fluids for CONUS, Arctic, or storage conditions; and replacing the three existing fluids with one. During the next three years, deficiencies such as poor lubrication properties and rubber incompatibility which showed up in laboratory testing were lessened by the incorporation of small amounts of additives to the fluids. Laboratory evaluation, including stroking tests based on SAE specifications and storage tests for packaging and preservative properties, established that a silicone fluid could be formulated to provide heavy-duty and arctic-type performance and the preservative properties required by the current brake fluids and packaging fluid. The remaining question of suitability under all operating conditions required the conduct of a field test. During March and April 1973, therefore, tests were initiated to obtain experience with silicone fluids in operational vehicles

Three silicone fluids (two water-intolerant and one water-tolerant) and a conventional specification fluid were installed in the brake systems of vehicles operated by Army units in three areas representing climatic extremes: tropical (Tropic Test Center, Panama Canal Zone); extreme cold (Arctic Test Center, Fort Greeley, Alaska); and desert (Yuma Proving Ground, Arizona).

The first year inspection was covered in USAMERDC Report 2132.* This portion of the test showed that the silicone brake fluids will equal or exceed the performance obtained from current specification fluids. The most significant improvement was found in Panama where numerous malfunctions due to corrosion occurred with brake systems using the specification fluid. There were no malfunctions with the silicone brake fluids.

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* James H. Conley, Robert Jamison, and Charles B. Jordan, "Silicone Brake Fluids: One-Year Field Test," USAMERDC Report 2132, AD A012849 (Feb 75).

In Yuma the general appearance of the systems with silicone fluids was somewhat better than those with the conventional fluids. However, no malfunctions occurred which were attributable to the fluids.

The same situation held true for the Alaskan portion of the test where the performance of the system which was operated with the silicone fluid for one year was comparable to those systems with the specification fluid.

This report contains the final results of the two-year field test of silicone brake fluids operating at TTC and YPG and the one-year test of two low-temperature fluids operating at ATC.

II. DETAILS OF TEST

Three silicone fluids (two water-intolerant and one water-tolerant) and a conventional specification fluid (VV-B-680) were used in Panama and Yuma. These silicones were used initially in Alaska. Testing on the water-intolerant fluids was discontinued midway through the test, however, because of possible crystallization at temperatures below minus 46°C (50°F), and two new silicones with improved low-temperature properties were substituted and compared to conventional MIL-H-13910 arctic brake fluid.

For these tests, new brake cylinder sets were packaged with fluid in the laboratory and shipped with new brake hoses to the appropriate area for installation on M 151, ¼-ton cargo vehicles and M 715, 1¼-ton vehicles. After one year, half the cylinders from Panama and Yuma were torn down on site and examined for condition of the metal parts and rubber compounds and for appearance of the fluid. Samples of the fluids were sent back to the laboratory. The cylinders were then reinstalled and brought back to level with fresh fluid, and the vehicles were returned to operation. Cylinders of the other vehicles were left undisturbed. After two years' operation all cylinders, hoses, and samples of the fluid were returned to the laboratory for final evaluation. In Alaska, all cylinders were returned for examination after one year's operation. In addition to visual examination of the fluids, water pick-up was determined by the Karl Fisher Method.

III. DISCUSSION

In Panama (Table 1), three of the four vehicles using the VV-B-680 fluid completed the second year of operation without a brake malfunction (numerous failures occurred during the first year) even though the cylinders were severely corroded. The fourth vehicle was reported missing in February 1975, and no data are available. During examination of the brake parts, a strong odor of gasoline and swelling of the

Table 1. Panama Inspection

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
HQ-7 USA2A055369 ¼-Ton *	VV-B-680	May 75/24	3980	Cylinder bore–satisfactory Piston–satisfactory Spring–satisfactory Secondary Cup–slight scuffing Primary Cup–slight scuffing	All cylinders–heavy rusting under pistons Pistons–heavy rust and gum Cups–light scuffing All springs–slight rusting	Moderate sediment % H_2O - 10.4	Moderate-to-heavy sediment % H_2O - 15.7 12.2 10.3 7.8
HQ-37 USA03M83668 1¼ Ton *	VV-B-680	May 75/24	3084	Cylinder–heavy rusting under secondary cup Piston–satisfactory Secondary cup–slight scuffing; appears to be swollen; hard to remove Primary cup–slight scuffing; odor of gasoline	Cylinders–1 wheel cylinder heavy rust under both pistons 1 wheel cylinder heavy rust under 1 piston; slight-to-moderate rusting under 1 piston 2 wheel cylinders–moderate rusting under both pistons; more under cups Pistons–3 pistons heavy gumming; 3 pistons moderate; 2 pistons light gumming Cups–2 moderate; 6 light scuffing Springs–satisfactory	Slight sediment Gasoline odor % H_2O - 5.3	Heavy sediment % H_2O - 11.6 4.8 10.1 4.1

Table 1. Panama Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
HQ-38 USA03M82568 ¾-Ton *	VV-B-680	May 75/24	1829	Cylinder- heavy rusting under secondary cup Piston- satisfactory Spring- satisfactory Secondary cup- slight scuffing; appears to be swollen; hard to remove Primary cup- moderate scuffing; light scoring at base Gasoline odor	Cylinders- heavy rusting under pistons in 3 cylinders; moderate rusting under pistons in 1 wheel cylinder Pistons- heavy rusting and gumming on piston in 3 wheel cylinders; moderate rusting and gumming on pistons in 1 wheel cylinder Cups- slight scuffing	Slight sediment Gasoline odor % H_2O- 6.8	Moderate-to-heavy sediment % H_2O- 7.6 2.5 5.3 10.5
HQ-21 USA02AJ1069 ¾-Ton *	U.C.	May 75/24	5100	Cylinder--satisfactory Piston -satisfactory Spring- satisfactory Secondary cup- satisfactory Primary cup- slight scoring	Cylinder--satisfactory Pistons -satisfactory Springs- satisfactory Cups- light scuffing	Slight sediment % H_2O- 0.5	Slight sediment % H_2O- 0.0 0.1 0.0 0.0
HQ-40 USA03M86468 1¼-Ton	U.C.	May 75/24	681	Cylinder- satisfactory Piston- satisfactory Secondary cup- slight scuffing Primary cup- moderate scoring and scuffing over secondary port; both cups swollen	Cylinder--satisfactory Piston--slight scoring and wear; no corrosion Cups--slight scuffing and scoring Springs- satisfactory	Clear Gasoline odor % H_2O- 0.3	Clear % H_2O- 0.0 0.1 0.0 0.3

Table 1 Panama Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
HQ-29 USA03M00968 1¼-Ton *	L.C.	May 75/24	5150	Cylinder--satisfactory Piston--satisfactory Springs--satisfactory Secondary cup--slight scuffing Primary cup--slight scuffing; both cups swollen	Cylinder--normal wear Pistons--slight scoring Cups--slight scuffing Springs--satisfactory	Clear Gasoline odor % H_2O 0.0	Clear % H_2O 1.4 0.7 0.1 0.2
HQ-8 USA2D6897 ¼-Ton	D.C.	May 75/24	4747	Cylinder--satisfactory Piston--satisfactory Secondary cup--satisfactory Primary cup--slight scoring and moderate scuffing Spring and check valve--slight corrosion	Cylinders--2 wheel cylinders show heavy corrosion in center bottom with normal wear in piston area; 2 wheel cylinders show slight corrosion in center bottom with normal wear in piston area Pistons--1 moderate scoring; 3 slight scoring; 4 normal wear Cups--1 moderate scuffing; 7 slight scuffing Springs--satisfactory	Clear % H_2O--0.0	Moderate sediment % H_2O 0.0 0.0 0.0 0.0
HQ-17 USA250738 ¼-Ton *	D.C.	May 75/24	3718	Cylinder--overall staining Piston--satisfactory Secondary cup--satisfactory Primary cup--slight scoring	Cylinder--3 wheel cylinders satisfactory; 1 wheel cylinder stain in center Pistons--2 (1 wheel cylinder) slight scoring	Clear % H_2O--0.0	Slight sediment % H_2O--0.5 0.0 0.1

Table 1. Panama Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date; Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
HQ-17 (Continued) USA250738 ¼-Ton				Spring and check valve slight-to-moderate corrosion	6 normal wear Cups–all slight scuffing Springs–satisfactory		
HQ-27 USA03M02168	D.C.	May 75/24	1378	Cylinder–satisfactory Piston–satisfactory Cups–swollen; secondary had to be forced out Strong odor of gasoline present Spring–satisfactory	Cylinders–2 satisfactory; 2 show slight corrosion in bottom center Pistons–2 moderate scoring; 6 normal wear Cups–satisfactory Springs–satisfactory	Clear Gasoline Odor % H_2O–0.5	Clear % H_2O–0.0 0.0 0.3 0.0
HQ-35 USA03M74468 1¼-Ton *	D.C.	May 75/24	10,733	Cylinder–satisfactory Piston–satisfactory Cups–swollen; secondary had to be forced out Strong odor of gasoline Spring–satisfactory	Cylinders–1 wheel cylinder slight pitting on bottom center; 1 wheel cylinder slight scoring at outside edge of one end; 2 wheel cylinder–satisfactory Pistons–5 moderate scoring 3 normal wear Cups–5 slight scuffing; 3 satisfactory Springs–satisfactory	Clear Gasoline Odor % H_2O–0.0	Clear % H_2O–0.1 0.0 0.0 0.3

Table 1. Panama Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
HQ-1 USA250771 ¼-Ton *	G.E.	May 75/24	3245	Cylinder bore–satisfactory Piston–satisfactory Spring–moderate corrosion Secondary cup–satisfactory Primary cup–slight scuffing	2 Wheel Cylinders–slight stain; 1 wheel cylinder–slight stain at one end; moderate stain at the other end; 1 wheel cylinder heavy rust both ends and center 2 Pistons–slight stain and scoring; 4 pistons moderate stain; 2 pistons heavy corrosion 1 Spring–satisfactory; 2 springs–heavy rust; 1 spring–moderate rust	Slight sediment Clear Amber % H_2O 1.5	Moderate sediment % H_2O 6.7 1.8 0.4 1.3
HQ-2 USA250730 ¼-Ton	G.E.	May 75/24	5328	Cylinder bore–moderate scoring left bottom Piston–satisfactory Secondary cup–satisfactory Primary cup–satisfactory Spring–heavy corrosion	2 Cylinders–heavy rust both ends; 1 cylinder heavy rust one end; 1 cylinder–moderate rust and stain both ends Cups–satisfactory 2 Springs–heavy corrosion; 2 springs–slight corrosion	Heavy sediment % H_2O 4.7	Heavy sediment % H_2O 1.4 0.5 0.0 4.2
HQ-31 USA03M56068 1¼-Ton *	G.E.	May 75/24	2766	Cylinder–heavy rusting at secondary Piston–satisfactory Secondary cup–heavy scuffing	All cylinders–heavy rust in piston area All pistons–heavy corrosion Cups–4 moderate scuffing; 4 slight scuffing	Slight sediment % H_2O 1.9	Moderate sediment % H_2O 3.2 0.7 1.6 1.6

Table 1. Panama Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
HQ-31 (Continued) USA03M56068 1¼-Ton				Primary cup–slight scuffing and scoring Spring–satisfactory	Springs–moderate rusting		
HQ-36 USA03M82668 1¼-Ton	G.E.	May 75/24	4753	Cylinder–slight rusting in secondary cup area Piston–covered with black residue Secondary cup–slight scuffing Primary cup–slight scuffing Spring–completely detinned	Cylinder–3 heavy rust both ends, 1 moderate rust both ends Pistons–3 heavy corrosion; 4 moderate corrosion; 1 light corrosion Cups–slight scuffing and scoring Springs–slight corrosion; 4 boots show polymer buildup	Black Gasoline Odor % H_2O 2.1	Heavy sediment % H_2O 6.2 3.0 1.3 0.4

* Vehicle inspected at one year. New fluid added.

secondary cup were noted in the master cylinders from the two 1¼-ton vehicles. Water pick-up in the fluid ranged from 2.5 to 15 percent.

The vehicles using the silicone fluids continued to operate trouble free during the second year. The cylinders with the Union Carbide (U.C.) and Dow Corning (D.C.) water-intolerant fluids were satisfactory, with the latter showing a tendency to stain and have slightly more corrosion of metal parts. The cylinders with the General Electric (G.E.) water-tolerant fluid showed considerably more corrosion than those with other silicone fluids but were still substantially better than those with the VV-B-680 fluid. The odor of gasoline and swelling of the secondary cup in the master cylinder were also noted in the 1¼-ton vehicles using the U.C. and D.C. fluids. It was not present in the vehicles using the G.E. fluid. The rubber cups had a slight-to-moderate scoring and scuffing with all the fluids under test.

In an investigation to determine the cause for the gasoline odor in the master cylinders of some of the 1¼-ton vehicles, test personnel learned from TTC personnel that the affected vehicles had been equipped with deep water fording kits. These kits vent the master cylinder into the air breather which, in turn, allows gasoline vapors to enter the master cylinder and cause the rubber cup swelling that was noted.

At Yuma Proving Ground, Arizona, all vehicles except one containing U.C. silicone fluid completed the second year of operation without a brake malfunction. Those brake parts were discarded inadvertently and the cause of malfunction could not be determined. Fluid performance was comparable to the Panama portion of the test. Visual inspection and pertinent data are shown in Table 2.

At Fort Greeley, Alaska, the vehicle containing MIL-H-13910, Arctic Brake Fluid, showed heavy corrosion of the wheel cylinders and scoring of the pistons. All the vehicles with the water-intolerant silicones gave comparable results, showing only slight stain of the cylinders and, with the exception of one vehicle using the D.C. fluid, showed no piston scoring (Table 3).

Photographs illustrating representative cylinders from each climatic area are shown in Figures 1 through 8.

Table 2. Yuma Inspection

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
SP-208 03B00469 1¼-Ton	VV-B-680	Oct 74/18	6986	No master cylinder returned	All cylinders show very heavy rust and corrosion All pistons show heavy gum All cups–slight scuffing		Heavy sediment % H_2O– 5.1 5.3
03J02268 1¼-Ton *	VV-B-680	Apr 75/24	4255	Moderate-to-heavy rust at bottom of cylinder bore Rust in reservoir Secondary cup–heavy scuffing Primary cup–heavy scuffing Piston–satisfactory Spring–detinned	All cylinders show heavy rust and corrosion All pistons–heavy corrosion and gum deposit Cups–moderate scuffing Springs–2 satisfactory; 2 detinned	Heavy sediment % H_2O–3.2	Heavy sediment % H_2O– 3.9 3.0 1.9 2.3
MS-6 2J8585 ¼-Ton *	VV-B-680	May 75/24	8069	Cylinder–moderate stain at forward end of bore Piston- satisfactory Secondary cup–heavy scuffing Primary cup–heavy scuffing Spring–satisfactory	All cylinders show heavy rusting All pistons show heavy gumming All springs–detinned	Moderate sediment % H_2O–3.7	Two drops recovered % H_2O– 5.8 11.5

Table 2. Yuma Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
MS-2 2K6397 ¾-Ton	VV-B-680	May 75/24	9117	Cylinder showed slight sludge Piston–satisfactory Secondary cup–moderate scuffing Primary cup–slight scuffing and scoring Spring–partially detinned	All cylinders–heavy rust and corrosion All pistons–heavy corrosion and gumming All cups–slight-to-moderate scuffing All springs–detinned	Heavy sediment % H_2O–3.0	Moderate sediment % H_2O–4.5 3.9 8.4 3.7
03J43568 1¼-Ton *	U.C.	Vehicle turned in for salvage; date not known; 12 months +	3347+	Cylinder–satisfactory Piston–satisfactory Secondary cup–moderate scuffing Primary cup–moderate scuffing and scoring Spring–satisfactory	Left front cylinder–slight stain Pistons–slight scoring Cups–satisfactory Spring–satisfactory Right front cylinder–slight stain Pistons–1 normal wear, 1 slight scoring Cups–slight scuffing Spring–satisfactory Left rear cylinder–slight stain Piston–slight scoring Cups–slight scuffing Spring–satisfactory	Moderate sediment Fluid clear % H_2O–0.5	Slight sediment in two wheels; clear amber in the other two % H_2O–0.6 0.0 0.0 0.4

Table 2. Yuma Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
03J43568 (Continued) 1¼-Ton					Right rear cylinder–slight stain Pistons–slight scoring Cups–slight scuffing Springs–satisfactory		
TP-593 3D67368 1¼-Ton	U.C.	Apr 75/24	1104	Cylinder bore–satisfactory Piston–satisfactory Secondary cup–slight scuffing Primary cup–moderate scuffing Spring–satisfactory	Left front cylinder–heavy stain in fluid area Pistons–slight scoring Cups–slight scuffing Spring–satisfactory Right front cylinder–slight stain Pistons–1 slight scoring 1 slight-to-moderate scoring Cups–moderate scuffing Spring–satisfactory Left rear cylinder–small area near bleeder valve shows heavy rust Pistons–normal wear Cups–slight scuffing Spring–satisfactory	Moderate sediment % H_2 0–0.0	Fluids clear; slight sediment % H_2 0–0.2 0.1 0.0 0.0

Table 2. Yuma Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
TP-593 (Continued) 3D67368 1¼-Ton					Right rear cylinder–slight stain Pistons–slight scoring Cups–satisfactory Spring–partially detinned		
MS-1 2N1756 ¼-Ton *	U.C.	May 75/24	6797	Cylinder–moderate stain at top of bore Piston–satisfactory Secondary cup–slight scuffing Primary cup–moderate scuffing Spring–satisfactory	Left front cylinder–slight stain and wear on both ends Pistons–slight stain Cups–slight scuffing Spring–satisfactory Right front cylinder–same as left front Left rear cylinder–same as left front Right rear cylinder–same as left front	Clear % H_2O–0.4	Clear % H_2O–0.7 0.2 0.2 0.4
MS-5 2J8403 ¼-Ton	U.C.	May 75/24	6463	Cylinder–moderate stain at top of bore Piston–satisfactory Cups–satisfactory Spring–satisfactory	Left front cylinder–slight stain and slight wear both ends Pistons–1 slight stain and scoring Cups–slight scuffing Spring–satisfactory	Clear % H_2O–0.4	Clear % H_2O–0.3 0.2 0.3

Table 2. Yuma Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
MS-5 (Continued) 2J8403 ¼-Ton			6317*	Master cylinder and right rear wheel cylinder replaced at 21½ months; parts not returned	Right front cylinder–same as left front Pistons–1 satisfactory; 1 slight scoring Cups–slight scuffing Spring–satisfact ; Left rear cylinder–same as left front except both pistons show slight scoring Right rear cylinder–slight stain *Pistons–satisfactory* Cups–slight scuffing Spring–satisfactory		
MS-25 03F50668 1¼-Ton	D.C.	Apr 75/24	4413	Cylinder–satisfactory Piston–satisfactory Secondary cup–severe cracking at base Primary cup–slight scuffing and scoring Spring–satisfactory	Left front cylinder–moderate stain in fluid area. Slight scoring at one end Pistons–1 slight scoring; 1 heavy *scoring* Cups–satisfactory Spring–satisfactory Right front cylinder–slight stain in fluid area		Clear % H_2O 0.1 0.1 0.3 0.0

Table 2. Yuma Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
MS-25 (Continued) 03F50668 1¼-Ton					Pistons–normal wear Cups–slight scuffing Spring–satisfactory Left rear cylinder–slight stain overall Pistons–normal wear Cups–slight scuffing Spring–satisfactory Left rear cylinder–slight stain overall Piston–normal wear Cups–slight scuffing Spring–satisfactory Right rear cylinder–slight stain in fluid area Pistons–1 satisfactory 1 slight scoring Cups–satisfactory Spring–satisfactory		
MS-8 2P8730 ¼-Ton *	D.C.	May 75/24	8462	Cylinder–satisfactory Piston–satisfactory	Left front cylinder–slight stain and scoring in piston area	Clear % H_2O–0.1	Clear % H_2O–1.3 0.2

Table 2. Yuma Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
MS-8 (Continued) 2P8730 ¼-Ton				Secondary cup–moderate scuffing Primary cup–slight scuffing Spring–satisfactory	Pistons–slight stain Cups–slight scuffing Spring–satisfactory Right front cylinder–slight stain Piston–slight scoring Cups–satisfactory Spring–satisfactory Right rear cylinder–slight scoring on both ends Pistons–1 slight scoring; 1 slight stain Cups–slight scuffing Spring–satisfactory		
MS-70 2R0799 ¼-Ton	D.C.	Jan 75/21	13252	Cylinder–satisfactory Piston–satisfactory Secondary cup–slight scuffing Primary cup–moderate scuffing and scoring Spring–satisfactory	Left front cylinder–slight stain Pistons–moderate scoring Cups–slight scuffing Spring–satisfactory Right front cylinder–slight stain on both ends	Moderate sediment Fluid clear % H_2 0–0.3	Clear % H_2 0–0.0 0.1

Table 2. Yuma Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
MS-70 (Continued) 2R0799 ¼-Ton					Pistons–1 slight stain; 1 moderate stain Cups–slight scuffing Spring–satisfactory Left rear cylinder–slight wear both ends Pistons–slight scoring Cups–slight scuffing Spring–detinned Right rear cylinder–spot of corrosion on bottom in fluid area Pistons–moderate stain Cups–slight scuffing Spring–satisfactory		
MS-21 03M41668 1¼-Ton *	G.E.	Apr 75/24	11514	Cylinder–slight overall rusting Piston–satisfactory Secondary cup–satisfactory Primary cup–slight chipping; 3 blisters Spring–detinned	Left front cylinder–slight scoring both ends Pistons–heavy scoring Cups–moderate scuffing Spring–detinned Right front cylinder–	Heavy sediment Fluid green % H_2O–0.8	Moderate sediment Fluid amber % H_2O–0.3 0.9 1.1 0.1

Table 2. Yuma Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
MS-21 (Continued) 03M141668 1¼-Ton					slight stain Pistons–1 heavy scoring 1 slight scoring Cups–slight scuffing Spring–detinned Left rear cylinder– slight overall stain; light pitting on one end Pistons–1 moderate scoring; 1 light scoring Cups–slight scuffing Spring–detinned Right rear cylinder– moderate scoring on end; slight scoring on other Pistons moderate to heavy scoring Cups–slight scuffing Spring–detinned		
MS-26 03E92768 1¼-Ton	G.E.	Apr 75/24	8751	Cylinder–moderate overall rusting in bore Piston–satisfactory Secondary cup–slight scuffing	Left front cylinder– slight pitting at one end; other satisfactory Pistons–slight scoring 1 moderate-to-heavy scoring	Heavy sediment Fluid black % H_2O–0.0	Moderate-to- heavy sediment Fluid dark amber % H_2O–0.9 1.4 0.0 0.0

Table 2. Yuma Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
MS-26 (Continued) 03E92768 1¼-Ton				Primary cup - slight scuffing Spring - partially detinned	Cups - slight scuffing Spring - partially detinned Right front cylinder slight pitting both ends Pistons - moderate scoring Cups - satisfactory Spring - detinned Right rear cylinder - slight scoring one end; other satisfactory Pistons - 1 heavy scoring; 1 slight-to-moderate scoring Cups - satisfactory Spring - satisfactory Left rear cylinder - slight pitting one end; slight scoring both ends Pistons - heavy scoring Cups - satisfactory Spring - detinned		

Table 2. Yuma Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
MS-3 2F0458 ¼-Ton *	G.E.	May 75/24	6606	Cylinder–slight overall stain Piston–satisfactory Secondary cup–very slight scuffing Primary cup–moderate to heavy scoring Spring–partially detinned	Left front cylinder–slight overall stain Pistons–1 heavy etch, 1 slight scoring Cups–slight scuffing Spring–detinned Right front cylinder moderate stain in fluid area Pistons–normal wear Cups–slight scoring Spring–detinned Left rear cylinder–slight overall stain Pistons–moderate scoring Cups–slight scuffing Spring–detinned Right rear cylinder–slight overall stain Pistons–slight scoring Cups–slight scuffing Spring–detinned	Two drops Clear % H_2O 0.0	

Table 2. Yuma Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
MS-7 2J8621 ¼-Ton	G.E.	Apr 75/24	7599	Cylinder–slight overall stain Piston–satisfactory Secondary cup–satisfactory Primary cup–slight scuffing and scoring Spring–partially detinned	Left front cylinder–moderate stain in fluid area Piston–1 moderate scoring; 1 slight scoring Cups–light scuffing Spring–detinned Right front cylinder–moderate to heavy rusting in fluid area and under one piston Pistons–1 slight scoring; 1 moderate scoring Cups–1 slight scuffing; 1 moderate scuffing Spring–detinned Left rear cylinder–moderate rust in fluid area Pistons–1 light scoring; 1 moderate scoring Cups–slight scuffing Spring–detinned Right rear cylinder–moderate rusting in fluid area Pistons–1 light scoring; 1 moderate scoring Cups–slight scuffing Spring–detinned	Heavy sediment % H_2O 0.3	Slight sediment % H_2O 0.0 0.0 0.0

* Vehicle inspected at one year. New fluid added.

Table 3. Alaska Inspection

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
USA03N56068 1¼-Ton	MIL-H-13910	Dec 75/12	3319	Cylinder bore–ring of corrosion under secondary cup. Overall stain of bore Piston–heavy corrosion and stain Secondary cup–moderate scuffing Primary cup–slight scoring and scuffing. Slight chipping at base Spring–detinned	2 cylinders–heavy corrosion and sludge in fluid area 1 cylinder–moderate to heavy corrosion; one spot on side and top. Heavy spots under one cup 1 cylinder–moderate stain and heavy sludge in fluid area 3 pistons–normal wear 2 pistons–moderate to heavy scoring 2 pistons–slight scoring 1 piston–pitted (13 spots) 2 cups–moderate scuffing and scoring 1 cup–moderate scuffing 1 cup–slight scuffing and scoring 3 cups–slight scuffing 1 cup–satisfactory	Dark % H_2O- 1.1	Dark Moderate *sediment* % H_2O- 2.4 1.9 2.4 2.6

Table 3. Alaska Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
USA03N56068 (Continued) 1¼-Ton					2 springs–detinned 2 springs–satisfactory		
2K6108 1¼-Ton	U.C.	Apr 75/8	3191	Cylinder bore–satisfactory Piston–satisfactory Spring–satisfactory Secondary cup–slight scuffing Primary cup–satisfactory	All cylinders–slight stain 7 pistons–slight stain 1 piston–slight etch All cups–satisfactory Springs–satisfactory	Slight sediment % H_2O–0.2	Slight sediment % H_2O–0.6 0.3 –.1 0.0
2J9248 ¼-Ton	U.C.	Apr 75/9	1920	Cylinder bore–satisfactory Piston–satisfactory Spring–satisfactory Secondary cup–satisfactory Primary cup–slight scuffing and scoring at base	All cylinders–slight stain All pistons–slight stain Cups–satisfactory Springs–satisfactory	Amber Slight sediment % H_2O–0.5	Clear amber % H_2O–0.3 0.3 0.1 0.6
2J9374 ¼-Ton	U.C.	Apr 75/9	3082	Cylinder bore–satisfactory Piston–satisfactory Spring–satisfactory Secondary cup–satisfactory Primary cup–moderate scuffing; slight scuffing	All cylinders–slight stain All pistons–slight stain Cups–satisfactory Springs–satisfactory	Slight sediment % H_2O–0.2	Clear % H_2O–0.2 0.2 0.0 0.1

Table 3. Alaska Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
2J9202 ¾-Ton	D.C.	Apr 75/9	2045	Cylinder bore- satisfactory Piston-satisfactory Spring-satisfactory Secondary cup-satisfactory Primary cup-slight scuffing	All cylinders-slight stain All pistons-slight stain Cups-satisfactory Springs-satisfactory	Clear % H_2O-0.2	Clear % H_2O-0.0 0.5 0.2 0.5
2J9490	D.C.	Apr 75/9	5000	Cylinder bore-dark ring about 1 inch from push rod end Piston-satisfactory Spring-satisfactory Secondary cup-satisfactory Primary cup-slight scuffing and chipping	2 cylinders-slight stain 1 cylinder-slight scoring and stain 1 cylinder-slight corrosion one end 2 pistons-slight stain 1 piston-moderate scoring 1 piston-heavy scoring 1 piston-slight scoring 1 piston-slight to moderate scoring 1 piston-moderate etch 1 piston-moderate to heavy etch	Clear % H_2O-0.2	Clear % H_2O-0.0 0.5 0.2 0.5

Table 3. Alaska Inspection (Cont'd)

Vehicle Number and Type	Fluid	Inspection Date/ Months of Service	Total Mileage	Visual Inspection		Fluid Appearance	
				Master Cylinders	Wheel Cylinders	Master Cylinders	Wheel Cylinders
2J9490 (Continued)					4 cups–slight scuffing 1 cup–moderate scuffing 3 cups–satisfactory		
02H80172 ¼-Ton	D.C.	Apr 75/9	1206	Cylinder bore–satisfactory Piston–satisfactory Spring–satisfactory Secondary cup–satisfactory Primary cup–moderate scuffing and scoring	All cylinders–slight stain All pistons–slight stain 7 cups–satisfactory 1 cup–slight scoring Springs–satisfactory	Clear % H_2O- 0.7	Clear % H_2O- 0.6 1.8 0.1 0.2

IV. CONCLUSIONS

This program has shown that silicone brake fluid will equal or exceed the performance obtained from current specification fluids in conventional hydraulic brake systems. The water-intolerant silicones show considerably less corrosion than either the conventional fluids or the water-tolerant silicone fluid after the two-year period. After one year in the arctic, both the water-intolerant and the water-tolerant silicones were comparable in performance.

Based on this study and previous laboratory evaluations, silicone brake fluids have demonstrated their potential for use in the bulk of the Army fleet, which is composed of vehicles under 10,000 pounds gross weight and equipped with conventional hydraulic brake systems.

During this test period, however, laboratory tests conducted by a brake parts manufacturer indicated a potential problem with silicone fluids in vacuum over hydraulic brake systems used on vehicles of over 10,000 pounds gross weight. Since the Army fleet includes vehicles with this type of hydraulic brake system, further studies and tests are being conducted to resolve the problem.

The swelling of the rubber cups in the master cylinders of vehicles equipped with the deep-water fording kit can produce brake system failures regardless of the fluid used.

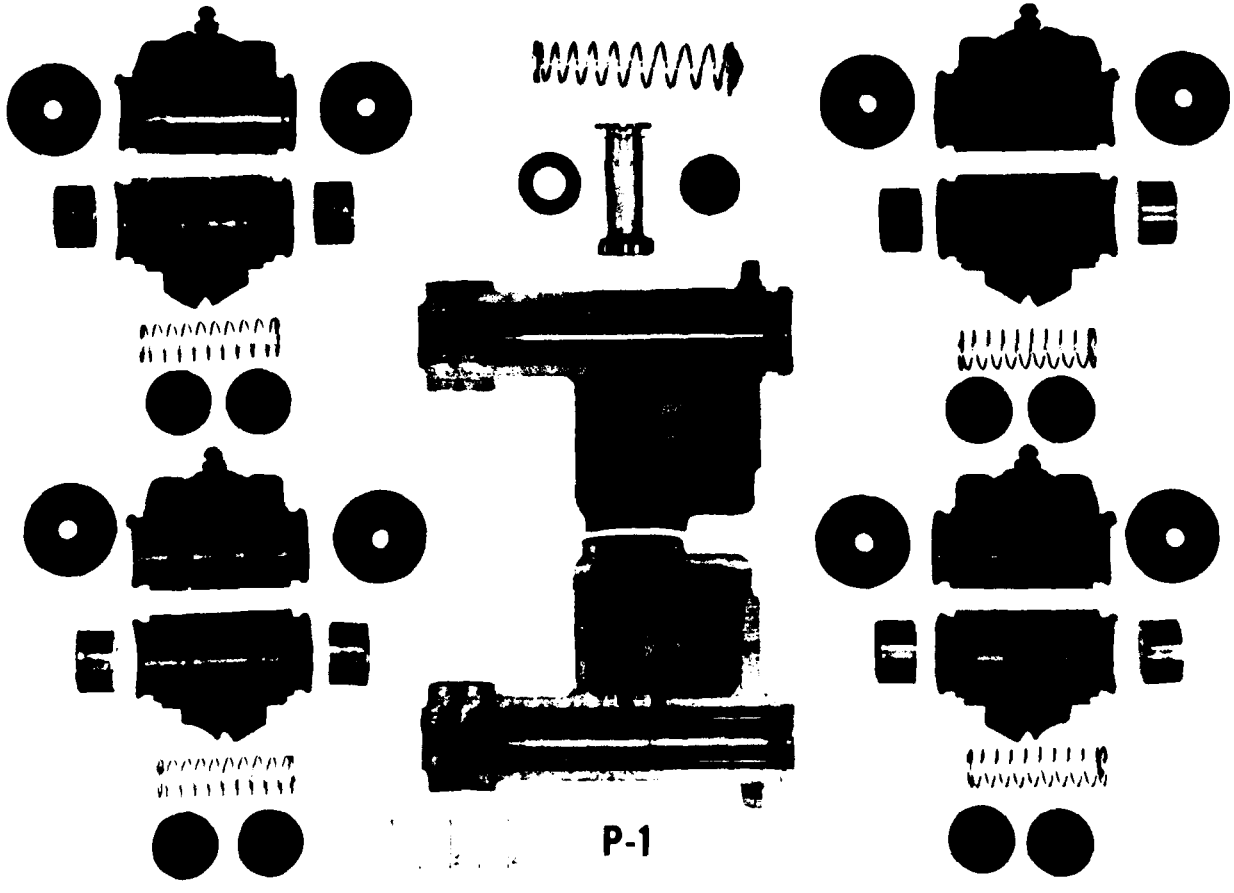

Figure 1. Typical set of cylinders after 2 years' operation at TTC with VV-B-680 fluid.

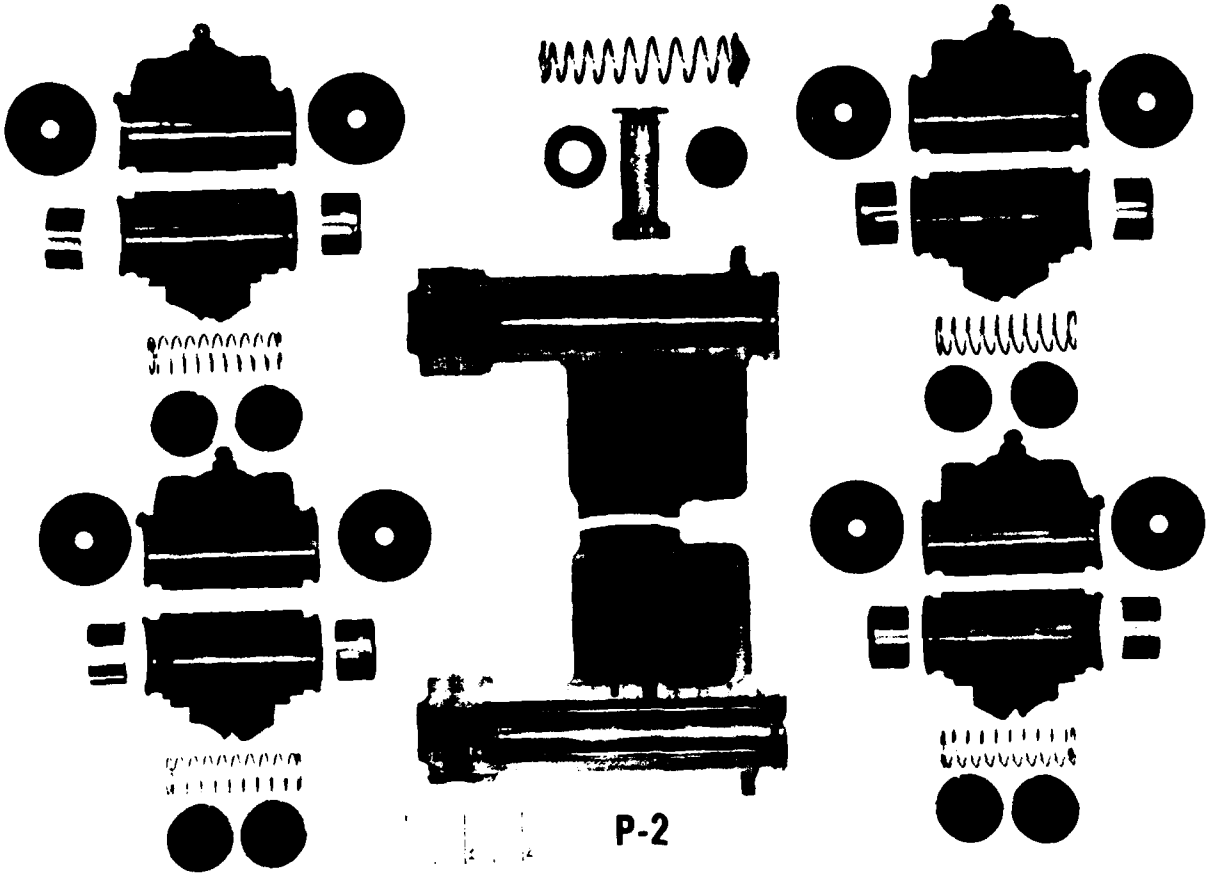

Figure 2. Typical set of cylinders after 2 years' operation at TTC with water-intolerant silicone.

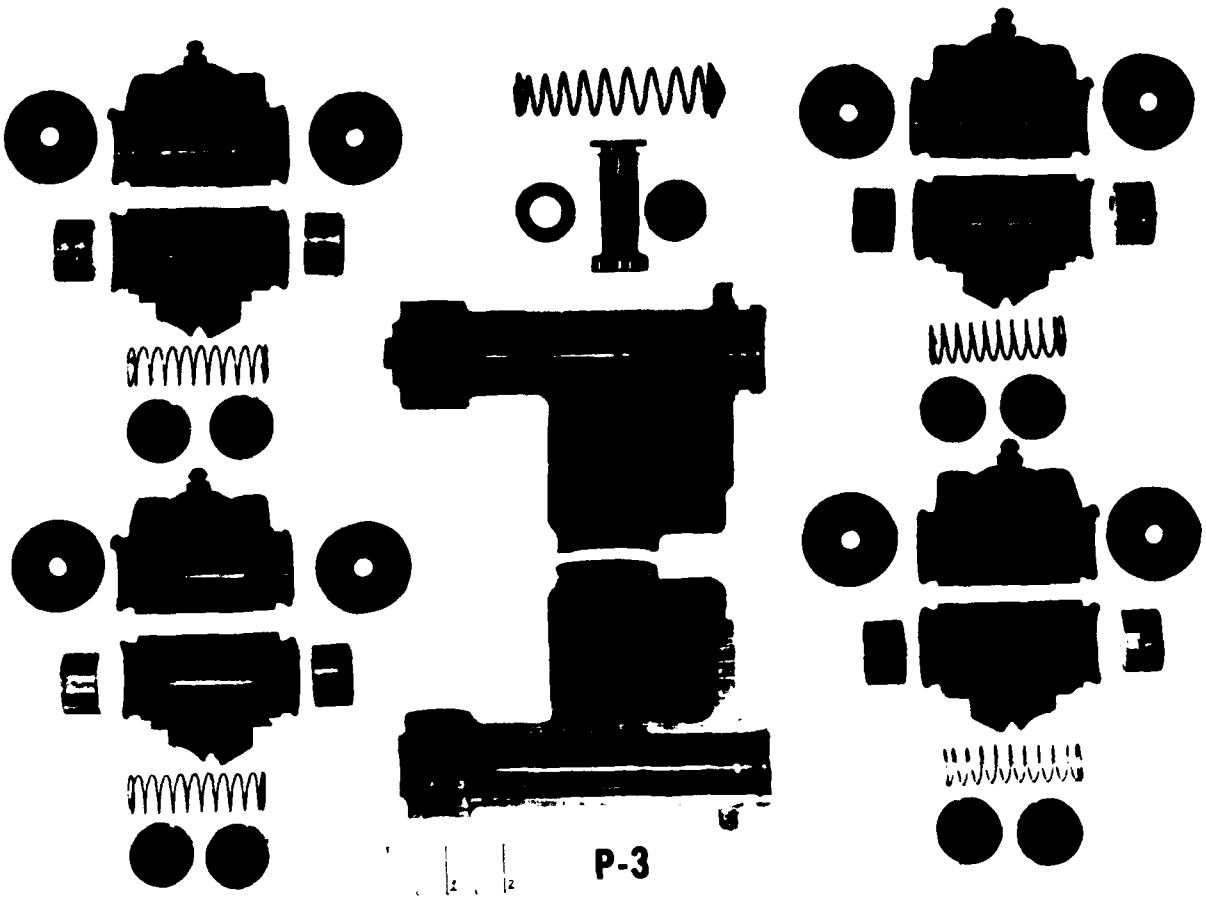

Figure 3. Typical set of cylinders after 2 years' operation at TTC with water-tolerant silicone.

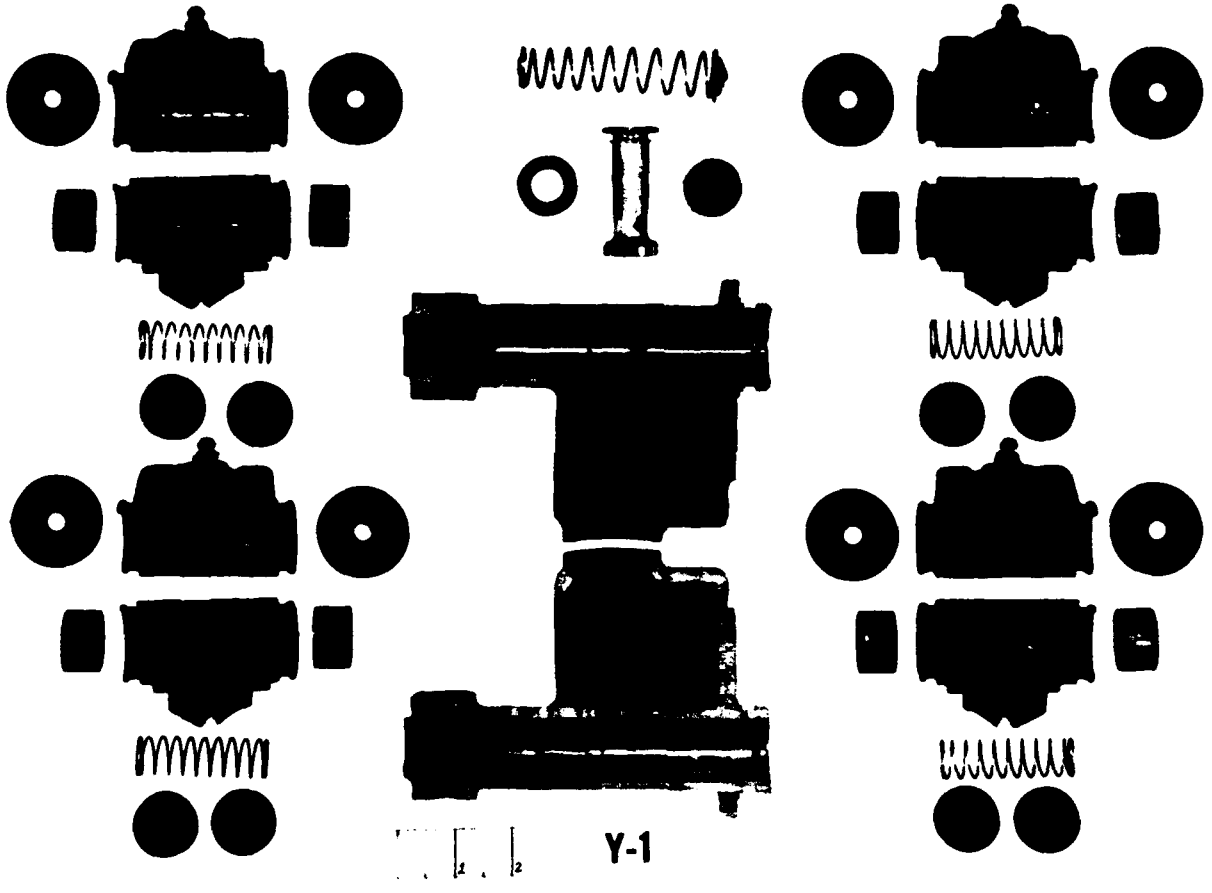

Figure 4. Typical set of cylinders after 2 years' operation at YPG with VV-B-680 fluid.

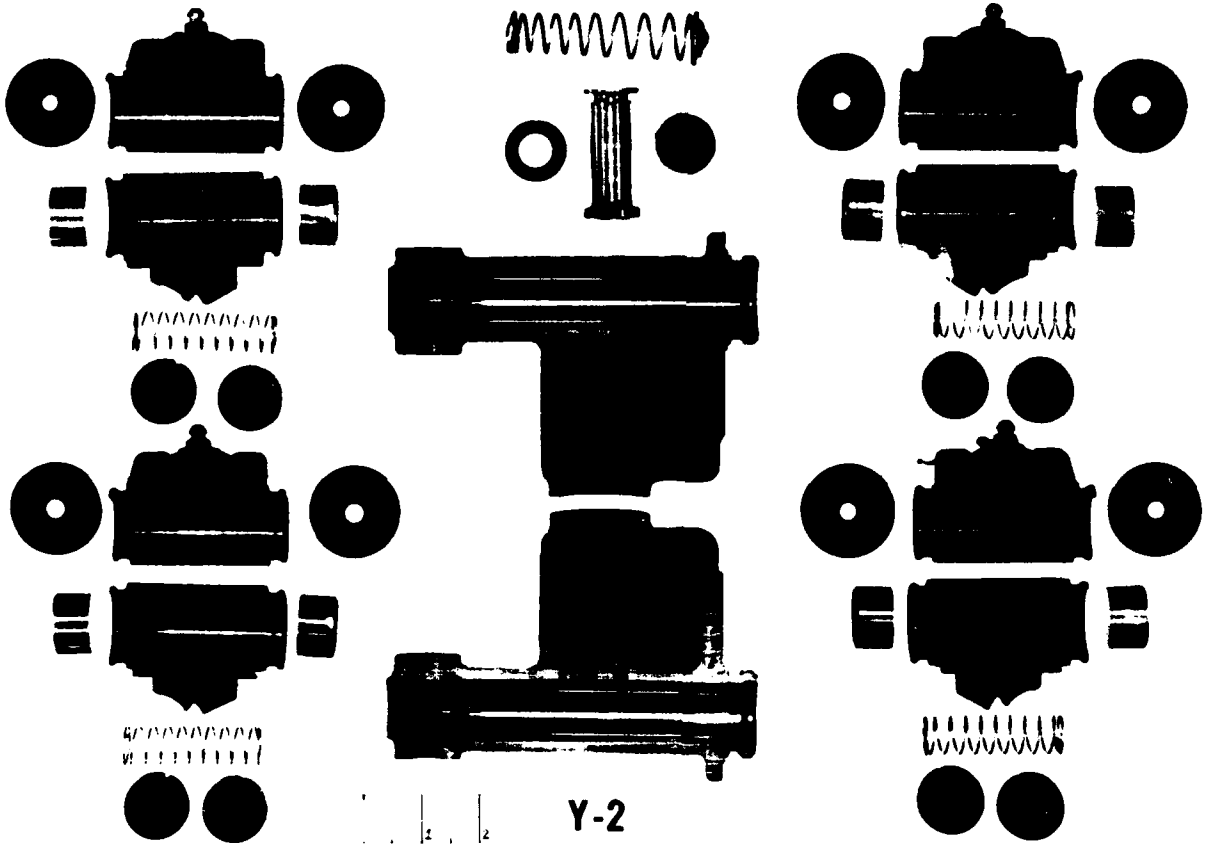

Figure 5. Typical set of cylinders after 2 years' operation at YPG with water-intolerant silicone.

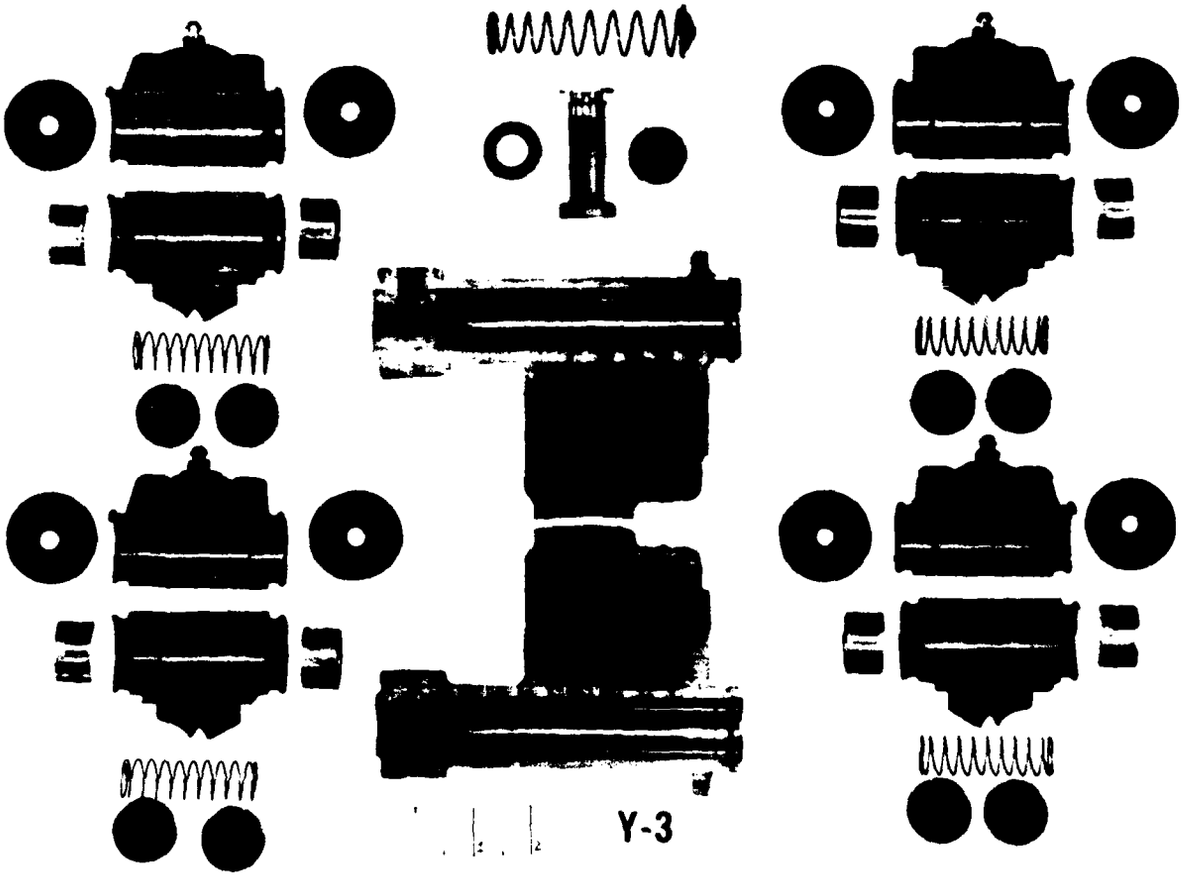

Figure 6. Typical set of cylinders after 2 years' operation at YPG with water-tolerant silicone.

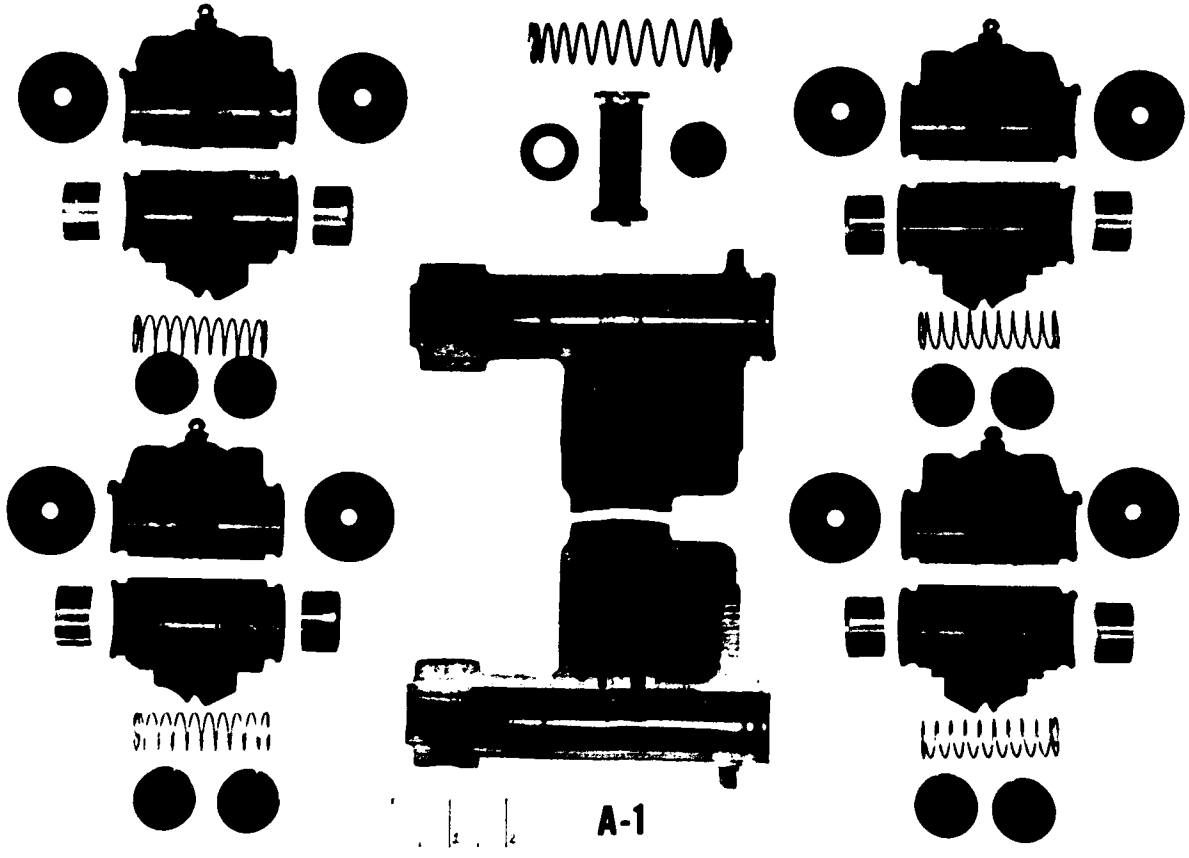

Figure 7. Typical set of cylinders after 1 year's operation at ATC with MIL-H-13910 fluid.

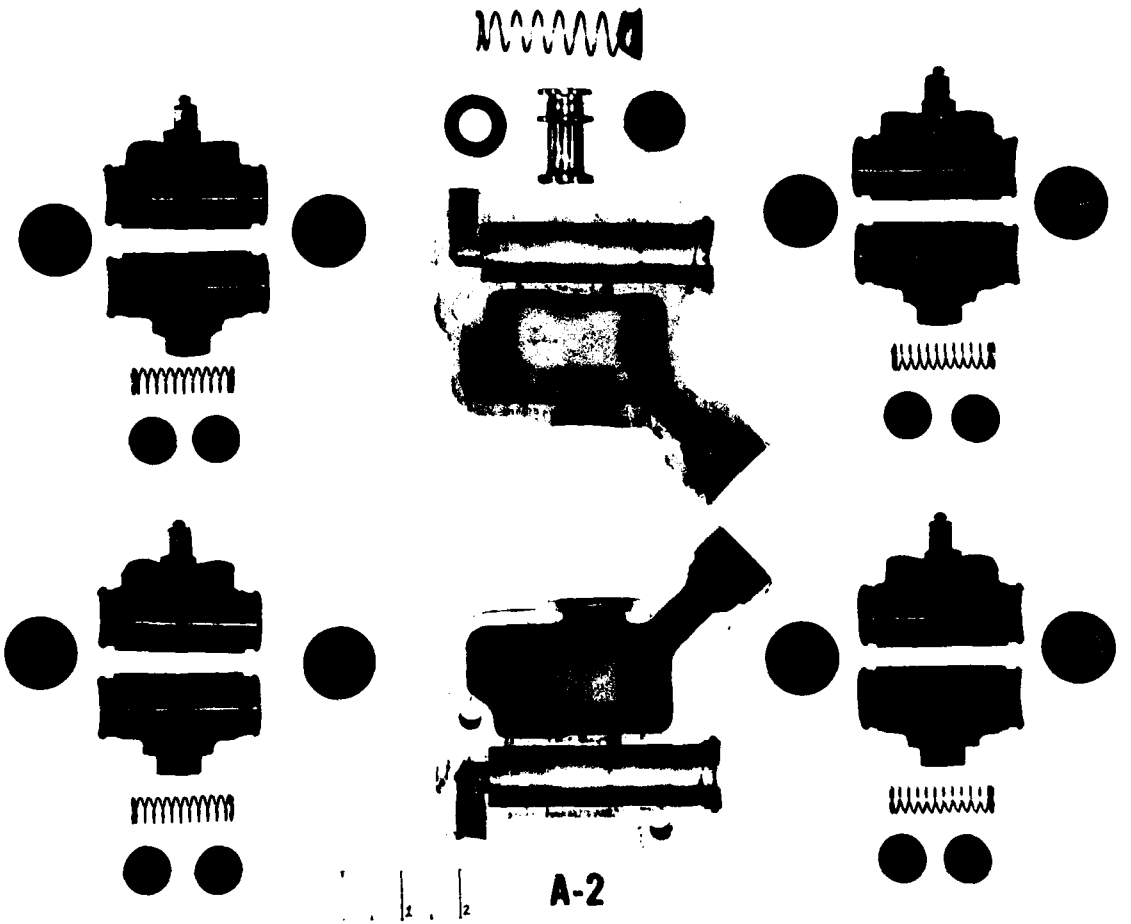

Figure 8. Typical set of cylinders after 1 year's operation at ATC with water-intolerant silicone.

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